Statistical Analysis of Field Strength Location Variability for UHF Multimedia Broadband Services

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***Abstract*—-This paper investigates the location variability of the field strength for dimensioning broadcast networks targeting mobile reception. A statistical analysis of empirical data from three European cities is performed for services in UHF band, specifically in TV bands IV and V (470-860 MHz). This work demonstrates that currently used values based on ITU-R P.1546-1 are too pessimistic and lead to inefficient network dimensioning.**

***Index Terms*—digital broadcasting systems; DVB; OFDM; single frequency networks.**

I. Introduction

THE location variability is a term referring to the standard deviation of the field strength, due to small-scale fading, over a small area inside the service area, typically represented by a square of 100x100 m^2. The location variability is a key parameter in dimensioning radiocommunication infrastructures, with major impact on portable and mobile coverage.

Network planning tools are based on simulation algorithms where theFrom the link budget point of view, the location variability effect is usually considered in the form of a log-normal location correction factor targeting a desired (required) coverage [1]. The value of the location correction factor can be obtained theoretically from the log-normal function of the field strength distribution provided the location variability is known.

Most recommendations consider a value for the location variability of 5.5 dB for wideband signals in Very High Frequency (VHF), Ultra High Frequency (UHF) and S Bands. This value is exclusively based on a cell size resolution of 100x100 m^2, which is the typical terrain grid resolution for planning broadcast networks [2]. Previous studies from the authors suggested that this value was pessimistic [3], [4]. In addition, the value of the cell size resolution of 100x100 m^2 has been inherited from analogue planning and it was mainly conditioned by digital terrain database available in the 90s.

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However, this consideration is no longer valid for network deployment in urban areas for mobile and portable receivers where a resolution of 25x25 m^2 in suburban environments and 5x5 m^2 in urban areas is the current practice.

Currently, experimental developments are ongoing for different mobile broadcast systems: Digital Video Broadcasting-Terrestrial 2 (DVB-T2) [5], Advanced Television System Committee-Mobile/Handheld (ATSC-M/H) [6] and the future system DVB-Next Generation Handheld (DVB-NGH) [7].

In this context, this work presents the results of an empirical analysis of the location variability for cell sizes between 5x5 m^2 and 500x500 m^2 and proposes a more accurate value. The results can be used in future digital broadcast network planning. The study is based on extensive DVB-T measurement campaigns carried out in the UHF band in three cities, Bilbao and Madrid in Spain and Ghent in Belgium.

The letter is organized as follows. First, field measurement campaigns are described. In Section III the methodology proposed in order to analyze gathered data is exposed. Section IV shows the obtained results and finally the main conclusions are summarized.

II. Measurement Campaigns

The present study is based on three measurement campaigns carried out in metropolitan areas of different cities: Madrid and Bilbao in Spain and Ghent in Belgium. The received power level was measured along different planned routes with variable length. The samples were measured using a calibrated field meter with a receiving antenna with an omnidirectional horizontal pattern placed on top of the measurement vehicle at a height of 2 meters above the ground level. The measurement positions were acquired with a GPS (Global Positioning System) device.

One set of measurements was carried out in Bilbao and Madrid [3], Spain, gathering field data on channel 68 (850 MHz) of the UHF Band with a bandwidth of 7.61 MHz. The network in Madrid The network consisted of three transmitters (a main transmitter with two auxiliary gap fillers) providing coverage in the city center and its surrounding areas. In Bilbao there was a main transmitter and also a secondary one that was used to fill some of the shadowed areas of the previous one. ThisBoth set up corresponds theoretically to a single frequency network (SFN), but in practice, there was a low overlapping between coverage areas of the transmitter and gap fillers so it can be considered as Low Dense SFN. The measurement area was mostly urban. A total of 75 routes in Madrid and 34 in Bilbao were measured.

The second group of data was obtained in the city of Ghent [4], where measurements were recorded at 602 MHz using a single transmitter, so it can be considered a multiple frequency network (MFN) environment. The signal bandwidth was also 7.61 MHz. The Ghent measurement area was mostly suburban, and a total of 106 routes were measured.

III. Analysis Methodology

The theoretical value of the location correction factor, $M_{Theor}(dB)$, can be derived from the location variability assuming a log-normal distribution for the electric field variability [1] using (1).

$$M_{Theor}(q) = Q_i(q/100).\sigma_L(dB) \qquad (1)$$

This factor depends on the accumulative inverse function, $Q_i(q)$, of the normal field distribution probability, the coverage target, q(%), and the mean value of the location variability, $\sigma_L(dB)$ for the considered cell size. The coverage target, q(%), represents the percentage of receiving locations inside the cell size where the electric field strength level will be higher than its median value.

All the power level measurement points along a route were grouped into segments of a drive length corresponding to different small area sizes (from 5x5 m^2 to 500x500 m^2). For statistical analysis purposes all the segments containing samples with a received power level close to the noise floor of the spectrum signal analyzer were discarded (-90 dBm) and segments shorter than the 90% of the length corresponding to the considered small area size were also not considered valid.

For each segment, route and measurement area, mean, maximum and minimum statistical values of the location variability are determined. Also, the 50^{th}, 70^{th}, 95^{th} and 99^{th} percentiles of the received field strength level, E_q, were calculated in order to determine empirically the location correction factor for different coverage targets.

$$M_{Empir}(q) = E_q - E_{50} \qquad (2)$$

In order to ensure that the field strength samples were statistically representative, the recommended practice by the European Radiocommunication Committee (ERC) was followed [8]. A minimum distance between samples of 0.8λ was imposed to the database by re-sampling. In addition, oversampling was avoided by removing the measurements separated less than 0.2λ. In practice, the analysis of the results has shown that the sub-sampling condition did not have a significant impact on the final results.

The propagation prediction models provide an estimated median value of the received field strength, E_{50}, for each small coverage area (with a size depending on the considered cell resolution) inside the service area. In order to determine if a receiving location is covered, this value needs to be corrected by adding the location correction factor accordingly to the corresponding coverage target (q). The values for the coverage target for each type of service (mobile/portable and outdoor/indoor) are specified in the implementation guidelines of the different standards [5], [9].

IV. Results

The accuracy of the log-normal approximation of the variation distribution was analyzed. In order to verify this assumption, Figure 1 compares the theoretical values (derived from the log-normal expression, in Formula 1, Section III) and the empirical values (obtained from the measurement campaigns by means of Formula 2, Section III) of the location correction factors for different coverage targets (70%, 95% and 99%) and different cell sizes. These values represent the average values of the three data sets. For increasing cell sizes, the location variability increases due to the higher variability of the electric field strength level. It can be observed that the theoretical values slightly underestimate the empirical location correction factor for 70%, 90% and 95% coverage targets and slightly overestimate it for the 99% coverage target. Anyway, the differences are always below 0.5 dB and so, it can be assumed that the electric field variability is log-normally distributed with independence of the selected cell size.

This means that the location correction factor needed to ensure a required coverage target, q(%), can be accurately derived from the mean value of the location variability.

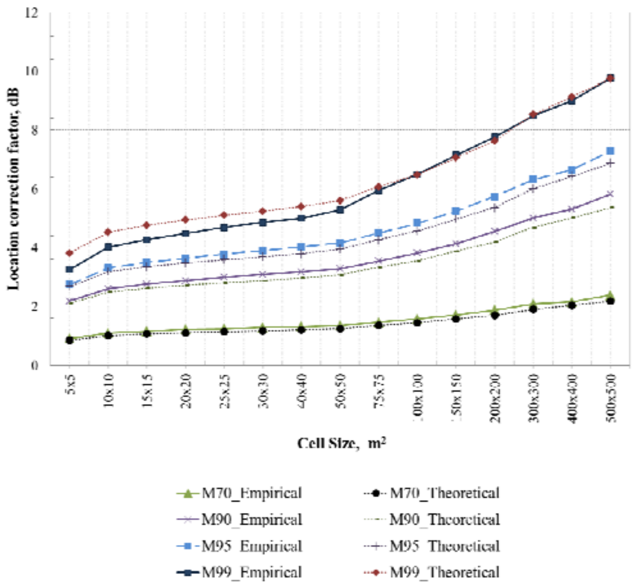

Fig.1. Comparison between theoretical and empirical values of the location correction factor in the measurement campaigns for different cell sizes in the three cities under study

The results for the outdoor location variability are summarized in Figure 2, which shows the average, minimum and maximum of the location variability values as a function of the cell size for different cities. The measured mean value of the location variability for a cell size of 100x100 m^2 is significantly lower than the value of 5.5 dB recommended by the International Telecommunications Union – Radiocommunications sector (ITU-R) [2] and European Telecommunications Standard Institute (ETSI) [9].

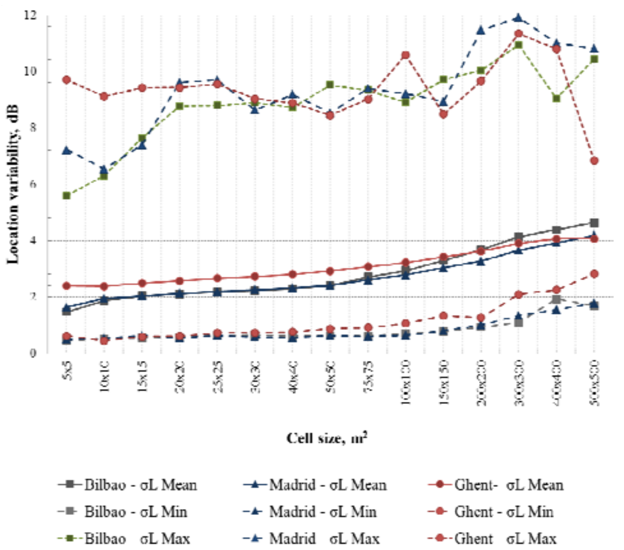

Fig.2. Mean, maximum and minimum of the location variability (σ_L) obtained in Bilbao, Madrid and Ghent for different cell sizes

As expected, the smaller the cell size, the lower mean value of the location variability. However, the difference between cell sizes of 10x10 m^2 and 100x100 m^2 is lower than 1 dB.

The results obtained for the cities in Spain are practically the same up to a cell size of 100x100 m^2. Differences up to 0.5 dB are obtained for cell sizes larger than 100x100 m^2. This is due to the large-scale fading, which has a remarkable influence for distances larger than 40λ [1]. Its effect depends significantly on the topology of the city and causing the difference for cells higher than 100x100 m^2. The detailed analysis of routes with the highest mean value of the location variability showed that those are trajectories rapid transition between line of sight and shadowing. The other case associated to high variation values was found in segments close to a river, where the reflections over the water increase the location variability.

Comparing measurements from Spain with those recorded in Ghent, it can be observed that when the cell size is smaller than 100x100 m^2, the mean value of the location variability for Ghent is higher. This could be due to the topology of the transmitting network, that is, SFN topology reduces the field strength variability in Madrid and Bilbao cases. The possible influence of SFN operation in location variability for cell sizes between 10x10 m^2 and 100x100 m^2 is lower than 0.5 dB. If the cell size is higher than 100x100 m^2, the mean value of the location variability is lower in the case of Ghent. This is due to the large scale fading differences caused by the specific characteristics of the environment of the mentioned city (mainly suburban).

It should be noted that nowadays the available cellular network planning tools work typically using DTM (Digital Terrain Model) information with a resolution of 5 meters in urban applications and 25 meters for suburban environments. The recommended values for the location variability accordingly with the obtained on average for the three data sets (Figure 2) is 1.5 dB and 2.2 dB for cell sizes of 5x5 m^2 and 25x25 m^2 respectively.

V. Conclusions

An empirical study to evaluate the field strength variation over a small geographical area for planning purposes has been presented in this paper. The main conclusion of this work is that the current values recommended by ITU-R and ETSI are pessimistic for SFN and MFN scenarios, different reception environments and digital terrain database granularities sizes below 100x100 m^2 (“small areas” according to the planning procedures). In that case, the mean value of the location variability is always lower than 3 dB.

The results show that the location correction factor to ensure a required coverage target can be derived accurately from mean value of the location variability. The recommended value for location variability is 1.5 dB for a cell size of 5x5 m^2 and is 2.2 dB for a cell size 25x25 m^2.

The presented results are essential in order to improve coverage planning for new digital standards in UHF band such as DVB-T2, DVB-NGH or ATSC M/H.

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References

[1] Lee, W. C. Y., “Mobile communications engineering: theory and applications”. MacGraw Hill. 1998

[2] *International Telecommunications Union ITU-R P.1546-3,* “Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz”, 2007

[3] Angueira, P.; Velez, M.M.; De La Vega, D.; Arrinda, A.; Landa, I.; Ordiales, J.L.; Prieto, G.; , "DTV (COFDM) SFN signal variation field tests in urban environments for portable outdoor reception," *Broadcasting, IEEE Transactions on* , vol.49, no.1, pp. 81- 86, Mar 2003
doi: 10.1109/TBC.2003.808738

[4] Plets, D.; Joseph, W.; Verloock, L.; Tanghe, E.; Martens, L.; Deventer, E.; Gauderis, H.; , "Influence of Reception Condition, MPE-FEC Rate and Modulation Scheme on Performance of DVB-H," *Broadcasting, IEEE Transactions on* , vol.54, no.3, pp.590-598, Sept. 2008 doi: 10.1109/TBC.2008.2000735

[5] *European Telecommunications Standard Institute*, “Implementation Guidelines for a Second Digital Terrestrial Television Broadcasting System (DVB-T2). Draft TR 102 831 V0.10.4, Jun. 2010

[6] *Advanced Television Systems Committee*, “ATSC Recommended Practice: Guide to the ATSC Mobile DTV Standard”. Doc. A/154, Apr. 2011

[7] *European Telecommunications Standard Institute*, "TM-H NGH Study Mission report: Guidelines for evaluation of radio transmission," ITU-R Recommendation M.1225, Jun. 2008.

[8] *European Radiocommunication Committee (ERC),* “Recommendation ERC (00)08, field strength measurements along a route with geographical coordinate registrations”, Oct. 2003

[9] *European Telecommunications Standard Institute*, “DVB-H Implementation Guidelines”. ETSI TR 102 377 V1.4.1 , Sept. 2006